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Report to the Chairman, Subcommittee
on Defense, Committee on
Appropriations, House of
Representatives

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SPACE LAUNCH

Cost Increases and Schedule Delays in the Air Force's Titan IV Program





United States
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National Security and
International Affairs Division

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The Honorable John P. Murtha
Chairman, Subcommittee on Defense
Committee on Appropriations
House of Representatives

Dear Mr. Chairman:

This report, prepared at your request, discusses the Air Force's Titan IV program's evolution, cost and schedule estimates, and contract status.

We are sending copies of this report to the Secretaries of Defense and the Air Force; the Director, Office of Management and Budget; and other interested parties.

Please contact me at (202) 275-4268 if you or your staff have any questions concerning this report. Other major contributors to this report are listed in appendix IV.

Sincerely yours,

A handwritten signature in cursive script that reads "Nancy R. Kingsbury".

Nancy R. Kingsbury
Director
Air Force Issues

Executive Summary

Purpose

The Titan IV launch vehicle will launch some of the nation's highest priority space systems, including a ballistic missile attack early warning system, a military communication satellite system, and various classified systems. The scope and cost of the program to research, develop, procure, and launch the Titan IV vehicles have changed dramatically over the last 5 years. The Chairman, Subcommittee on Defense, House Committee on Appropriations, requested that GAO report on the Titan IV program's evolution, cost and schedule estimates, and contract status.

Background

In 1984 the Department of Defense called for a launch system that would complement the space shuttle and better ensure access to space for certain national security payloads. In 1985 the Air Force contracted with Martin Marietta Corporation for 10 launch vehicles, later called Titan IVs. The Titan IV program has evolved from a short-term program to acquire and launch 10 vehicles at a cost of \$2 billion to an ongoing program to acquire 55 and launch 41 vehicles through the mid-1990s at an estimated cost of \$15 billion. After 1995 the Air Force plans to acquire and launch about 10 vehicles per year. The Air Force reported that the first Titan IV launch on June 14, 1989, was successful.

Results in Brief

The Titan IV program's cost estimate through fiscal year 1995 increased from \$12.7 billion in March 1988 to \$14.6 billion in October 1989. The Air Force will fund \$8.3 billion of the \$14.6 billion, and other Titan IV users will fund the remainder.

As of July 1989, the total price of the contract for 23 vehicles was over \$5.5 billion, including contractor profits, fees, and incentives of over \$675 million. In December 1989, 18 vehicles were added to the contract, which increased its total price to almost \$7.4 billion, including up to \$930 million in contractor profits, fees, and incentives.

The Air Force delayed 6 of the 10 Titan IV launches planned for fiscal years 1989 and 1990. Further delays may occur because the Air Force will not have vehicles available for four launches planned during fiscal years 1990 and 1991.

Principal Findings

Program Cost Increases

Between March 1988 and October 1989, the program office estimate for the Titan IV increased by \$1.9 billion. The March 1988 estimate included the cost to research, develop, procure, and launch 48 Titan IVs. The October 1989 estimate included the cost to research, develop, and procure 7 additional Titan IVs, for a total of 55, but launch 7 fewer, for a total of 41.

The Air Force and other, non-Department of Defense users of the Titan IV launch vehicle fund the program. Of the 55 vehicles planned to be acquired through fiscal year 1995, 21 are to be used by the Air Force. The Air Force will pay an average of about 115 percent more for each vehicle and about 155 percent more for each launch than the Titan IV's other users primarily because it will fund most of the Titan IV's research and development and launch facilities.

Contract Price Increases

Between December 1987 and July 1989, the contract for 23 vehicles increased by about \$1 billion to \$5.5 billion. By December 1989 the contract price increased \$1.9 billion, and the number of vehicles grew to 41. If options for 8 additional vehicles are exercised, the contract price for 49 vehicles would be about \$7.8 billion. In addition, as of July 1989, the Air Force estimated it would have to add about \$2.3 billion to the contract for modifications not yet included in the contract.

The cost overrun on the Titan IV contract was \$209 million as of July 1989. According to Air Force officials, the overrun was primarily due to production problems and the underestimation of engineering work. As of July 1989, the Air Force estimated the overrun at contract completion would be about \$298 million.

Schedule Delays

Six of the 10 Titan IV launches planned in 1988 for fiscal years 1989 and 1990 were postponed because of launch site preparation delays and payload reschedulings. Also, 4 of the 10 launches scheduled as of October 1989 for fiscal years 1990 and 1991 may be delayed because only 6 vehicles are to be delivered during that period. In addition, the completion dates for 3 Titan IV launch facilities have slipped up to 20 months, to the early to mid-1990s.

Recommendations

GAO is not making recommendations in this report.

Agency Comments

GAO did not request written agency comments on this report. However, GAO discussed a draft of this report with Department of Defense and Air Force officials and incorporated their comments where appropriate.

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Abbreviations

DD	Department of Defense
GAO	General Accounting Office

Introduction

In 1984 the Department of Defense (DOD) called for a launch system that would complement the space shuttle and better ensure access to space for certain national security payloads. In February 1985 the Air Force contracted with Martin Marietta Corporation for 10 expendable launch vehicles¹ and planned to launch 2 each year from 1989 through 1993 from a single launch facility at the Cape Canaveral Air Force Station, Florida. The Air Force subsequently named the vehicle the Titan IV.

The Titan IV consists of a 119-foot, 2-stage liquid propellant core vehicle; 3 liquid-fueled rocket engines; 2 solid rocket motors; payload coverings of 5 different lengths; and an upper stage,² if necessary. Titan IVs have various configurations. A Titan IV with a Centaur upper stage will launch 10,000-pound class payloads to geosynchronous³ or 12-hour orbits, a Titan IV with an inertial upper stage will launch 5,000-pound class payloads to geosynchronous orbit or 40,000-pound class payloads to low earth orbit, and a Titan IV without an upper stage will launch 30,000-pound class payloads to low earth orbit. The Air Force's estimates of how well each configuration can perform are shown in appendix I.

Starting in fiscal year 1992, the Air Force plans to use an upgraded solid rocket motor on the Titan IV. The requirements and estimated capabilities for the configurations using the upgraded motor are shown in appendix II.

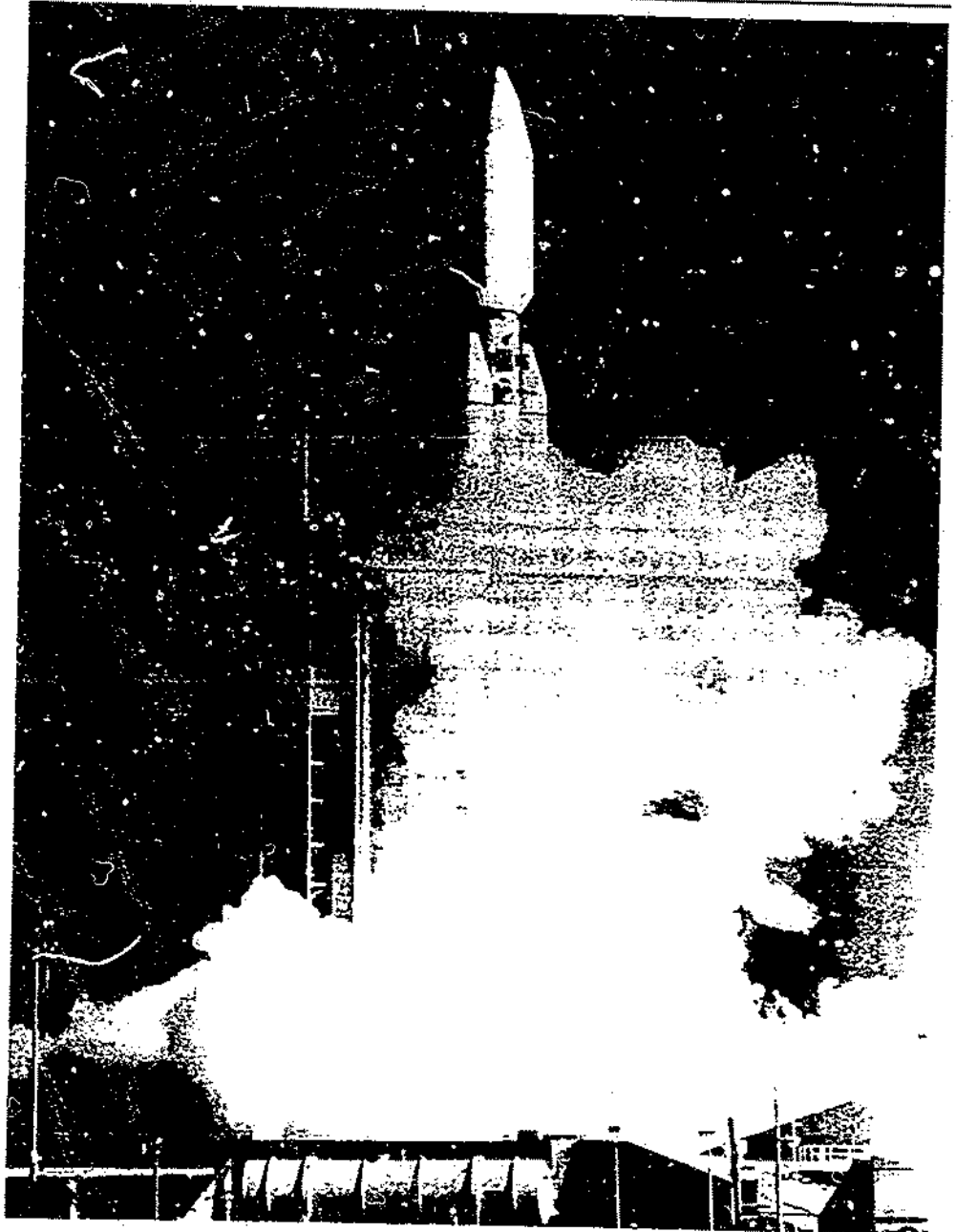
The Titan IV will be used to launch some of the nation's highest priority space systems, such as a ballistic missile attack early warning system, the Milstar military communication satellite system, the ballistic missile Boost Surveillance and Tracking System, and various classified systems. On June 14, 1989, the Air Force launched the first Titan IV from Cape Canaveral. The Air Force reported that the launch was successful. Figure 1.1 shows a Titan IV being launched.

¹An expendable launch vehicle is a disposable, unpiloted launcher.

²An upper stage provides propulsion to carry a payload from a lower to a higher orbit around earth.

³In geosynchronous orbit, a satellite orbits the earth but maintains the same relative position to it.

Figure 1.1: Titan IV Being Launched



Source: DOD

In 1986, after the space shuttle Challenger accident, the Air Force added 13 Titan IVs to the original contract, for a total of 23. The Air Force also planned to add two Titan IV launch facilities—one modified and one new—at Vandenberg Air Force Base, California.

In September 1987 the Air Force requested additional Titan IVs because the National Aeronautics and Space Administration delayed the space shuttle's first flight after the Challenger accident and reduced the future maximum number of planned shuttle flights per year from 16 to 14. The Air Force also planned another Cape Canaveral launch facility, bringing the total planned number of launch facilities to four. In December 1989 the Air Force added 18 vehicles, with options for up to 8 more, to the current contract.

The Air Force plans to acquire 55 and launch 41 Titan IVs through fiscal year 1995. After that time the Air Force plans to acquire and launch about 10 Titan IVs per year. For example, through fiscal year 1997 the Air Force plans to have acquired 78 and launched 60 Titan IVs, assuming that 4 operational launch facilities are available.

Objectives, Scope, and Methodology

The Chairman, Subcommittee on Defense, House Committee on Appropriations, requested that we report on the Titan IV program's evolution, cost and schedule estimates, and the contract status. We did our work at the Air Force Systems Command Space Systems Division, El Segundo, California, and Air Force Headquarters and the Office of the Secretary of Defense, Washington, D.C. We obtained and analyzed DOD, Air Force, and contractor documents and studies; cost and schedule estimates; budget data; and the Titan IV contract. We also interviewed DOD and Air Force personnel responsible for the Titan IV program.

We performed our review from November 1988 to December 1989 in accordance with generally accepted government auditing standards. As requested, we did not obtain written agency comments on a draft of this report. However, we discussed a draft of this report with DOD and Air Force officials and incorporated their comments where appropriate.

Cost Estimates Have Increased

From March 1988¹ to October 1989 the program office's estimate of the Titan IV program's cost through fiscal year 1995 increased by \$1.9 billion, from \$12.7 billion to \$14.6 billion. This increase is expected to buy seven more vehicles but seven fewer launches than in March 1988. The estimate also includes the cost of Titan IV launch facilities. As of June 1989, three of the facilities were estimated to cost over \$741 million, an increase of about 61 percent since early 1988.

The Titan IV program is funded by the Air Force and by other, non-DOD users of the program. The Air Force pays for most of the research and development and other costs, such as launch facilities and services. Consequently, the Air Force will pay about 115 percent more per vehicle and about 155 percent more per launch than other Titan IV users.

Total Program Estimate Increases

As of October 1989, the program office planned to acquire 55 and launch 41 vehicles through fiscal year 1995 at an estimated cost of \$14.6 billion. This estimate is 15.1 percent higher than the March 1988 estimate of \$12.7 billion to acquire and launch 48 vehicles. The \$1.9 billion increase will buy seven additional vehicles, but seven fewer will be launched. Table 2.1 details these changes.

Table 2.1: Cost Estimates Through Fiscal Year 1995

Dollars in millions				
Funding by the Air Force	Mar. 1988 estimate	Oct. 1989 estimate	Change	
			Amount	Percent
Research, development, test, and evaluation	\$1,839.6	\$2,653.7	\$814.1	44.3
Missile procurement	3,305.8	3,982.2	676.4	20.5
Other procurement	0.0	47.9	47.9	^a
Military construction	482.0	264.0 ^b	-218.0	-45.2
Operations and maintenance	1,534.0	1,365.5	-168.5	-11.0
Subtotal	\$7,161.4	\$8,313.3	\$1,151.9	16.1
Funding by other users	5,510.0	6,275.3	765.3	13.9
Total	\$12,671.4	\$14,588.6	\$1,917.2	15.1

Note: The estimates do not include the cost of the inertial upper stage, which is provided as government-furnished property under the Titan IV contract.

^aThis percent change is not shown because the base year is zero.

^bThis amount does not include most of the estimated cost of launch facilities, which are included in other elements of the cost estimate.

¹These estimates were presented in our report, DOD Acquisition Programs: Status of Selected Systems (GAO/NSIAD-88-160, June 30, 1988).

Program office estimates differ from those in the Selected Acquisition Report.² Information on how Titan IV costs are reported in the Selected Acquisition Report is in appendix III.

Funding by the Air Force and Other Users

Other users of the Titan IV program reimburse the Air Force for the hardware costs of their launch vehicles. Cost sharing between the Air Force and the other users is negotiable for all other program costs.³ The Air Force's cost per vehicle and launch, as of October 1989, are 114.5 and 154.5 percent higher, respectively, than for other users primarily because the Air Force pays for most of the Titan IV's research and development. The Air Force will also fund at least \$542 million of other users' Cape Canaveral launch services costs and will provide more funding than other users for the solid rocket motor upgrade and launch facilities.

Of the 55 vehicles planned to be acquired through fiscal year 1995, the Air Force will fund 21 and the other users will fund 34. On a per vehicle basis, the other users will pay \$184.6 million and the Air Force will pay \$395.9 million, or 114.5 percent more. On a per launch basis, the other users will pay \$207.2 million and the Air Force will pay \$527.4 million, or 154.5 percent more. Program officials said these unit cost differences are primarily the result of the Air Force paying most of the research, development, test, and evaluation costs and the Centaur upper stage's cost being spread over more vehicles and launches for the other users than for the Air Force. Specific examples contributing to the Air Force's higher unit costs include the following.

- The Air Force will fund all Cape Canaveral launch services, and the other users will fund all Vandenberg launch services. The Air Force does not plan any Titan IV launches from Vandenberg, but the other users plan 16 Titan IV launches through fiscal year 1995 from Cape Canaveral. Therefore, the Air Force will fund the other users' launch services at Cape Canaveral at an estimated cost of \$542 million to \$562 million.
- A program official said the Air Force and other users will pay the same solid rocket motor upgrade procurement cost, but the Air Force will fund over half of the upgraded motor's nonhardware costs while using

²The Selected Acquisition Report is a summary status report on major defense acquisition programs. It reflects a program manager's current "best estimate" of key performance, schedule, and cost goals; compares the estimates with baseline parameters; and explains any variances.

³DOD and Air Force officials stated that this arrangement is typical for programs such as the Titan IV.

9 of the first 25 sets.⁴ The other users will pay over half of the research and development costs for the upgraded motor, and the Air Force will pay other related costs, such as a new Cape Canaveral solid rocket motor assembly facility.

- The Air Force is funding the Titan IV launch facility modifications at Cape Canaveral, although 16 of the 30 launches scheduled there through fiscal year 1995 are for other users. The other users are funding modifications at one of the Vandenberg facilities, and the Air Force will fund the other Vandenberg facility. However, no Air Force launches are planned at Vandenberg through fiscal year 2000. A program official said the Air Force is paying for the second launch facility at Vandenberg because of its overall responsibility to provide space launch capability.

Launch Facility Estimates Increase

The Air Force's June 1989 cost estimate for three of the four Titan IV launch facilities is \$741.1 million, an increase of about \$280 million, or 61 percent, over the January 1988 estimate of \$461 million. The changes in each facility's cost estimate are shown in table 2.2.

Table 2.2: Cost Estimates for Launch Facilities

Dollars in millions					
Space launch complex	Location	Jan. 1988 estimate	June 1989 estimate	Increase	
				Amount	Percent
40	Cape Canaveral	\$135.0 ^a	\$310.0 ^b	\$175.0	129.6
41	Cape Canaveral	157.0	195.9 ^b	38.9	24.8
4E	Vandenberg	169.0	235.2 ^c	66.2	39.1
Total		461.0	741.1	280.1	60.8

^aAs of 1987.

^bThese estimates do not include funding for a new assembly facility for the upgraded motor at Cape Canaveral, which is estimated to cost \$147.5 million.

^cThis estimate is as of May 1989 and includes \$10.2 million for modifications required to accommodate the upgraded motor.

The estimate for modifying space launch complex 40 increased by \$175 million: \$100 million to add capability to launch the Titan IV with the Centaur upper stage, \$50 million to meet requirements that were unknown in January 1988, and \$25 million to cover increases in the estimated cost of existing requirements. The Air Force has modified space launch complex 41 for the Titan IV with the inertial upper stage and plans to continue modifying it for the Titan IV with the Centaur upper

⁴A set consists of two motors.

plans to continue modifying it for the Titan IV with the Centaur upper stage and the Titan IV without an upper stage. The estimated cost to modify the complex completely has increased because some of its facilities and systems were in worse condition than anticipated. The estimated modifications cost for space launch complex 4E increased because a remote control center was added, changes to accommodate the upgraded solid rocket motor were needed, and the estimated cost of existing requirements increased.

Four contractors have been developing concepts for the second Vandenberg Titan IV facility since August 1988. In December 1988 the Air Force expanded the contractors' scope of work to include concepts and cost estimates for converting space launch complex 6, the mothballed space shuttle launch facility,⁵ to a Titan IV facility. However, in September 1989, the Secretary of the Air Force decided to build a new launch facility. According to a Vandenberg official, the Air Force Council and Defense Science Board recommended a new facility because it would allow greater long-range adaptability to different vehicles and operating scenarios than a converted facility. Also, DOD could expect a better long-range return on investment in a new, rather than a converted, facility.

In the fiscal year 1990 authorization act for DOD, the Congress prohibited any funding for a new facility and placed certain funding restrictions on the second Vandenberg facility regarding the conversion of space launch complex 6. During our previous review, DOD officials told us that, as of April 1988, the estimated cost of converting space launch complex 6 to a Titan IV facility was \$441 million.

Air Force officials said they have not decided whether the second Vandenberg facility will use the "integrate on pad" system or the "integrate, transfer, and launch" system. With the former system, one vehicle at a time is built and processed on the pad and then launched. With the latter system, a vehicle is built and processed at various locations and transferred to the pad for launch. This system provides a higher launch rate, but it costs more. Although near-term mission forecasts do not indicate a launch rate requiring integrate, transfer, and launch capability, sites and access routes are to be preserved for such a system if launch rates increase sufficiently to warrant its use.

⁵For more information on this facility, see our report, Space Shuttle: The Future of the Vandenberg Launch Site Needs to Be Determined (GAO/NSIAD-88-158, Aug. 3, 1988).

Contract Price Has Increased

In February 1985 the Air Force signed a \$5 million contract with Martin Marietta to define a concept for a new launch vehicle. In June 1985 10 vehicles were added to the contract, which increased the contract's target price¹ to almost \$2.1 billion. Through early December 1987, the contract for 10 vehicles increased to about \$2.2 billion. At that time the Air Force added 13 vehicles to the contract, increasing its target price to over \$4.1 billion and the number of vehicles to 23. By July 1989 the target price of the contract for 23 vehicles had grown to about \$5.1 billion, and the total contract price² was over \$5.5 billion.

In December 1989 the Air Force added 18 vehicles to the contract, which increased the total contract price to almost \$7.4 billion and the number of vehicles to 41. The Air Force also included an option for up to eight additional vehicles. If the options are exercised, the total contract price would be about \$7.8 billion, including contractor and subcontractor profits, fees, and incentives of up to about \$1.2 billion. However, the contract does not yet include some significant costs related primarily to payload integration and solid rocket motors.

The Air Force projects a \$298 million cost overrun at contract completion. As of July 1989, the overrun was \$209 million. Also, \$128 million of planned work had not been completed as scheduled. Both the cost overrun and the schedule slippage are primarily due to contractor and major subcontractor problems, according to the Air Force.

Contract Structure

Martin Marietta Astronautics Group, Denver, Colorado, is the prime contractor responsible for producing the Titan IV's first and second stages and for providing overall systems engineering and integration, payload integration, and launch services. Eight major subcontractors are responsible for producing certain Titan IV components, as shown in table 3.1. Under a separate contract, Boeing Aerospace Company, Seattle, Washington, produces inertial upper stages, which are provided as government-furnished property under the Titan IV contract.

¹Target price consists of a target cost and a target profit.

²Total contract price includes the target price plus the cost of three items financed differently under the contract, as described later in this chapter, and all fees and mission success incentives available to the contractor and subcontractors.

Table 3.1: Major Subcontractors

Dollars in millions			
Subcontractor	Component produced	Subcontract price ^a	Estimated unit cost
General Dynamics Space Systems, San Diego, California	Centaur upper stage	\$951.8	\$52.0 ^b
Hercules Aerospace, Magna, Utah	Solid rocket motor upgrade	713.8	52.3 ^c
United Technologies Chemical Systems Division, San Jose, California	Solid rocket motor	665.5	41.6
McDonnell Douglas Astronautics Company, Huntington Beach, California	Payload fairing	340.3	14.8 ^d
Aerojet TechSystems Company, Sacramento, California	Liquid rocket engine	281.8	12.3 ^e
General Motors Delco Systems Operations, Goleta, California	Inertial guidance components	92.4	4.0
Cincinnati Electronic Corporation, Cincinnati, Ohio	Command receivers	9.5	0.4
Spacecraft, Inc., Huntsville, Alabama	Instrumentation	7.2	0.3

^aAs of May 1989.

^bActual contract cost

^cThis estimate is for a set of two engines as of October 1989 and includes the amortization of the subcontractor's research and development investment of about \$5 million per set, according to DOD and Air Force officials.

^dThe estimate is the average cost for five different size payload fairings

^eThis estimate is for a set of three engines

The first 23 vehicles under the contract consisted of 10 Titan IVs with the Centaur upper stage, 8 Titan IVs with no upper stage, 4 Titan IVs with the inertial upper stage, and 1 Titan IV whose configuration was to be determined. The actual cost of each Titan IV vehicle varies depending primarily on its configuration, as shown in table 3.2.

Table 3.2: Examples of Vehicle Hardware Costs

Dollars in millions	
Configuration and vehicle number	Amount
Titan IV with no upper stage (no. 11)	\$71.9
Titan IV with Centaur upper stage (no. 3)	128.9
Titan IV with upgraded solid rocket motors and Centaur upper stage (no. 7)	139.3

The Titan IV contract is primarily based on a target price consisting of both a target cost and a target profit. However, the financing of three items under the contract is arranged differently. The first item is associated with the Industrial Modernization Incentives Program, a DOD initiative to improve the national defense industrial base and encourage government contractors to improve their production processes. Under the first phase of this effort, Martin Marietta studied its manufacturing process at a cost of \$1.2 million, which it shared equally with the Air Force. Martin Marietta will use the study results to identify specific projects that warrant further study. If the Air Force agrees, the Air Force will fund the studies' cost. If Martin Marietta suggests a way of improving a production process, and the Air Force approves the suggestion, Martin Marietta will fund the improvement's implementation and share any savings with the Air Force according to a preestablished formula.

The second item involves payload integration, which is the process of integrating the satellite onto the upper stage or Titan IV vehicle. A Titan IV contracting official said that when the Air Force awarded the Titan IV contract, payload integration costs were uncertain and not included in the contract. The Air Force subsequently added some payload integration to the contract under an arrangement that the Air Force Systems Command believed would cause Martin Marietta to respond more quickly to Air Force changes. The Air Force plans to add the remaining payload integration under an incentive arrangement so that the Air Force can base its fee payment on the contractor's performance.

The third item involves the hydrostatic test fixture, an Air Force-owned facility used to test the Titan IV fuel tanks. The facility is currently unusable, and the Air Force will pay Martin Marietta to repair it for an estimated cost of \$3 million. Martin Marietta will not earn a profit or fee.

Contract Price for Up to 23 Vehicles

As the Titan IV contract grew during its first 4 years to 23 vehicles, its target profit increased about 13 percent faster than its target cost because, according to Air Force officials, Martin Marietta's financial risk increased as a result of adding 13 vehicles to the contract and for other reasons, such as the program expanding from a vehicle with one configuration launched from one site to a vehicle with multiple configurations launched from various sites. Table 3.3 shows various target cost, profit, and price changes as the contract grew from 10 to 23 vehicles.

Table 3.3: Changes in Selected Elements of the Contract for 10 and 23 Vehicles

Dollars in millions

	Contract for 10 vehicles			Contract for 23 vehicles			Percent change from June 1985 to July 1989
	June 1985	Dec. 1987	Percent change	Dec. 1987	July 1989	Percent change	
Target cost	\$1,906.5	\$1,976.4	3.7	\$3,755.1	\$4,609.0	22.7	141.8
Target profit	189.3	196.9	4.0	391.6	482.5	23.2	154.9
Target price	2,095.8	2,173.3	3.7	4,146.7	5,091.5	22.8	142.9
Ceiling price	2,287.8	2,371.5	3.7	4,506.0	5,512.7	22.3	141.0

Target profit was 10.5 percent of target cost as of July 1989, and the ceiling price was 119.6 percent of target cost.³ In addition to the \$482.5 million target profit, Martin Marietta would earn fixed fees of \$8.6 million. Furthermore, the contract provided for up to \$18.4 million in award fees and \$165.8 million in mission success incentives for the contractor, for a total of up to \$675.3 million in profits, fees, and incentives, or 14.3 percent of cost. The contract also included up to \$139.5 million for subcontractor incentives, making the total contract price over \$5.5 billion as of July 1989.

The \$18.4 million award fee is based on management effectiveness and technical and schedule performance in achieving initial launch capability. The Air Force may award up to \$5.5 million each at the completion of initial launch capability for the Titan IV with the inertial upper stage and the Titan IV without an upper stage and up to \$7.4 million at the completion of initial launch capability for the Titan IV with the Centaur upper stage. The Air Force declared that initial launch capability for the Titan IV with the inertial upper stage was achieved in February 1989, even though the first launch did not take place until mid-June 1989, and

³An Air Force Systems Division Titan IV contracting official said target profit is generally 10 percent of target cost and the ceiling price is generally 120 percent of target cost.

awarded \$3.85 million, or 70 percent of the \$5.5 million, to Martin Marietta. According to a program official, the Air Force determined that the launch delays from October 1988 to June 1989 were not totally Martin Marietta's fault. Program officials said any award fees not awarded will be available for Titan IV unfunded requirements.

The \$165.8 million mission success incentive represents about \$7.2 million for each of 23 successful launches. On the other hand, each failure caused by Martin Marietta will result in a \$45.3 million reduction in the combined target profit/mission success incentive pool, with target profit reduced first. If the Air Force determines that the contractor did not cause the failure, no mission success incentive is paid and no penalty is assessed. Instead, the mission success incentive will carry over to the next launch. If that launch is successful, Martin Marietta will earn two incentive fees. If no other launches are scheduled before the end of the contract, Martin Marietta will receive the incentive.

Price for the Follow-on Buy

On December 1, 1989, the Air Force added 18 vehicles and launches to the Titan IV contract at a target price of about \$1.6 billion, with options for up to 8 more vehicles. The target price includes a \$163 million profit. In addition, the contractor can earn \$81 million in award fees and incentives, and subcontractors can earn about \$18 million in incentives. These amounts do not include target prices, fees, or incentives associated with 10 sets of solid rocket motors or upgraded motors needed for the 18 vehicles,⁴ the 8 optional vehicles, or payload integration.

With the addition of the 18 vehicles, the total contract price has grown from over \$5.5 billion under the contract for 23 vehicles as of July 1989 to almost \$7.4 billion under the contract for 41 vehicles, including up to \$930 million in contractor profits, fees, and incentives and \$157 million in incentives for subcontractors. If options for all eight vehicles are exercised, the total contract price would be about \$7.8 billion, including contractor profits, fees, and incentives of up to \$992 million and incentives for subcontractors of over \$164 million.

There are requirements for all 18 vehicles and 2 of the 8 optional vehicles. The remaining six optional vehicles may be used to cover additional

⁴As discussed later in this chapter, there will be 8 sets of motors remaining from the contract for 23 vehicles. The Air Force plans to use them with the follow-on buy vehicles. Thus, only 10 more sets will be needed. These motor sets currently have a not-to-exceed value of \$907 million, including \$75 million for award fees and mission success incentives.

requirements that have not yet been identified. The two optional vehicles that have requirements were included in the contract as optional vehicles because they are not needed until after 1995.

On the basis of experience gained under the contract, the Air Force considers the follow-on buy's cost and schedule risks to be moderate and all other risks to be low. However, to prepare for the negotiation of the follow-on buy, the Air Force did a "should cost" review of Martin Marietta and its major subcontractors. This detailed assessment of materials, processes, management, and organizational effectiveness identified problems, including the existence of outdated technology that precluded the use of more cost-effective methods. According to a program official, the Air Force has made the production schedule an award fee criterion and has incorporated the Industrial Modernization Incentives Program into the Titan IV contract to encourage the contractor further to improve its production processes and save money.

Contract Modifications Contribute to Increases

As of July 1989, the Air Force had issued 283 contract modifications, 194 of which did not affect the contract's price. Two of the remaining 89 modifications, valued at \$4.1 billion, were for the 23 vehicles. The remaining 87 modifications increased the contract price by about \$1.1 billion. The five modifications shown in table 3.4 accounted for 77 percent of that increase.

Table 3.4: Selected Contract
Modifications With High-Dollar Value

Dollars in millions	
Reason for modification	Amount
Solid rocket motor upgrade	\$698.2
Mobile service tower improvements at space launch complex 4E	73.7
Inertial upper stage and payload integration/ launch support	46.6
Payload integration for the Titan IV with no upper stage	33.7
Other payload integration	23.1
Total	\$875.3

In addition, the Air Force and other users plan to add the following modifications valued at about \$2.3 billion to the contract through fiscal year 1995:

- \$847 million for payload integration.⁵

⁵ A Titan IV contracting official said the Air Force did not usually include payload integration in the contract because its cost was uncertain, since the specific payload designs were unknown.

- \$452.9 million for solid rocket motor upgrade modifications,⁶ and
- \$968.6 million (\$574.6 million from the Air Force and \$394 million from other users) for various other modifications.

Solid Rocket Motor Upgrade

In early 1988 the Air Force decided to upgrade the Titan IV's solid rocket motor because two payloads needed additional lift capability and the upgraded motor would be more reliable and use newer technology. In July 1988 Martin Marietta contracted with Hercules Aerospace for the first 15 sets of the upgraded solid rocket motor. This led to the contract modification with the largest dollar value not involving an increase in the number of vehicles. The changes from March 1988 to October 1989 to the cost estimate through fiscal year 1995 for upgraded motor sets are shown in table 3.5.

Table 3.5: Changes to the Solid Rocket Motor Upgrade Cost Estimate Through Fiscal Year 1995

Dollars in millions			
	Mar. 1988 estimate	Oct. 1989 estimate	Percent change
Research, development, test, and evaluation	*	\$367.5	
Missile procurement	\$1,760.0	1,407.3	
Aerospace ground equipment, integration, facility modification, and tooling	270.0	154.9	
Solid motor assembly facilities, railroad tracks, and nondestructive testing	153.0	111.0	
Centaur redesign and production	36.0	0.0	
Subtotal	2,219.0	2,040.7	-8.0
Credit	1,258.0 ^b	0.0	
Total^c	\$961.0	\$2,040.7	112.4

^aThis amount was included in missile procurement. Subsequently, the Congress directed that research development, test, and evaluation funds be separated from missile procurement funds.

^bThis amount included \$259 million for 7 solid rocket motor sets originally ordered but later canceled and \$999 million for 27 solid rocket motor sets budgeted for but not ordered.

^cThe March 1988 estimate is for 40 sets of motors; the October 1989 estimate is for 39.

The initial contract with United Technologies Chemical Systems Division was for 23 sets of the original solid rocket motor. After contracting for the upgraded motor, the number of Chemical System Division's solid rocket motor sets was reduced from 23 to 16. Thus, the Air Force will have a total of 31 solid rocket motor sets—16 solid rocket motors and

⁶This estimate does not include follow-on buy hardware.

15 upgraded motors—available for the first 23 vehicles under contract. A program official said the Air Force has assigned both the original and the upgraded solid rocket motors to 8 of the 23 vehicles as insurance against development and production delays for the upgraded motor.

The Air Force planned to use all 16 solid rocket motor sets on the first 23 vehicles and to begin using the upgraded motor in fiscal year 1992. However, a program official said that because of the March 1989 explosion at the Hercules Aerospace plant, which delayed testing of the upgraded motor by about 5 months, and because some scheduled payloads will not require the additional capability of the upgraded motor, the Air Force studied the costs and benefits of developing a second source of solid rocket motors. Among the options studied was the continued use of the original solid rocket motor.

In August 1989 the Air Force developed an acquisition strategy for continuing the production of components for the original solid rocket motor with an option to build motors from these components at a later date. In September 1989 production was authorized for components of seven solid rocket motor sets at a cost of \$70 million. The Air Force still had \$32 million available from the seven sets originally ordered but canceled. Therefore, the Air Force will need \$38 million in fiscal year 1990 to fully fund the component production, which will take 12 to 18 months to complete. Thus, the decision on assembling the motors will be delayed until fiscal year 1991.

Untimely Contract Modifications

Air Force regulations require the Air Force to definitize contract modifications within 180 days after they are issued or before the contractor completes 40 percent of the work. In March 1988 the program office identified a need to definitize contract modifications on time, noting that the contractor's proposals were late and its cost estimates were inadequate. About 1 year later the Air Force Audit Agency issued a report on 29 Titan IV contract modifications, valued at \$669 million, that had not been definitized. Of these, 21 modifications, valued at \$584 million, had not met the regulations. The agency reported that the delays resulted from Martin Marietta not submitting proposals on time and Air Force Space Systems Division contracting personnel not adequately monitoring Martin Marietta's compliance. As of July 1989, 14 modifications, valued at \$131 million,⁷ still had not been definitized. A program official said

⁷Of this amount, \$34.1 million had been negotiated but had not yet been included in the contract.

the delays were due to the long turnaround time in the Air Force Space Systems Division contracting office.

The program office reported that by September 1989 the contractor had significantly improved in submitting its proposals on time, but its cost estimates still remained a problem. The program office also reported that the number of Titan IV contracting personnel would be increased from 10 to 21.

Cost Overruns and Schedule Variances

As of July 1989, Martin Marietta had a cost overrun of \$209 million. According to the Air Force, the overrun was primarily caused by Martin Marietta's problems in producing the core vehicle and its underestimation of engineering work, United Technologies Chemical Systems Division's fabrication and delivery problems on the solid rocket motors, McDonnell Douglas' nose cone test failure and payload fairing delays, and Hercules Aerospace's problems with the upgraded solid rocket motor. Other causes of the overrun included more work than anticipated and technical problems in preparing the first Titan IV. Program officials said that most cost problems occur during the early stages of a program's research and development, which is what happened with the Titan IV program. They said Martin Marietta should recover from some of the problems during the production phase.

According to program officials, Martin Marietta underestimated the work involved to bring all the components together from various subcontractors and assemble the Titan IV vehicles. In addition, Martin Marietta experienced manufacturing schedule delays partly due to late deliveries from General Motors Delco Systems, McDonnell Douglas, and United Technologies Chemical Systems Division.

A program official said Chemical Systems Division has had fabrication problems with the solid rocket motors and is late in delivering parts for the second Titan IV and avionics for the solid rocket motors on the second through fourth vehicles. McDonnell Douglas experienced a nose cone test failure, which a program official said led to further design work and a 6-month delay in the test schedule. In addition, at Martin Marietta's direction, McDonnell Douglas performed additional work on the first 66-foot payload fairing, delaying its delivery approximately 90 days.

According to a program official, Hercules Aerospace was overly optimistic in estimating its upgraded motor development program and has

experienced difficulties coordinating the efforts of its subcontractors to meet the production schedule. The official said Hercules Aerospace did not provide its subcontractors with adequate requirements, so the subcontractors built and delivered inappropriate parts. Hercules Aerospace also had to redesign the upgraded motor case after it was tested and found to be weaker than required. Furthermore, in March 1989 an accidental explosion occurred at Hercules Aerospace's production facility. This delayed testing about 5 months, according to a program official. In June 1989 the Air Force approved Hercules' plan to recover from its earlier setbacks and establish a more realistic schedule.

Estimated Cost Overrun at Contract Completion

The Air Force estimated that the cost overrun at contract completion will be about \$298 million, whereas the Air Force Plant Representative Office at Martin Marietta estimated about a \$207 million overrun at contract completion. In contrast, Martin Marietta's estimate of the overrun at contract completion was about \$169 million. These estimated overruns do not include about \$88 million of management reserves⁵ available as of July 1989. Martin Marietta's estimate was the lowest because, according to a program official, the contractor has a plan to reduce the cumulative overrun by contract completion.

A program official believes that the cost overrun at contract completion will be about 5 percent, a proportion he believes indicates extraordinarily good performance on a contract of this size, technical scope, and with the number of program changes it has had in its first 5 years. The Air Force will pay 90 percent, and the contractor 10 percent,⁶ of any cost overrun at contract completion, up to the contract ceiling price. The contractor will have to absorb all costs beyond the ceiling price.

Program officials said they will judge Martin Marietta's cost performance early in the follow-on buy to determine if systematic problems exist. The Air Force Space Systems Division Commander reported in July 1989 that the Titan IV marginal cost performance was expected to continue after the first launch, but improvements were expected later. Program officials are conducting an in-depth examination of Martin Marietta's efforts to reduce the cost overrun, and they said they will reduce the award fee if the contractor's management of cost performance continues to be below standard.

⁵Management reserves are funds set aside to cover unforeseen costs that arise under contracts.

⁶The contractor's share of the cost overrun will be in the form of a reduction in the profit payable under the contract.

Work Not Completed on Schedule

Martin Marietta had planned to complete about 50 percent of the contract work by July 1989. It completed about 48 percent by that time, resulting in \$128.3 million of planned work not completed. This schedule variance was caused by subcontractor problems and technical difficulties while the first Titan IV was being prepared for launch.

United Technologies Chemical Systems Division's casting of solid rocket motors has slowed from 3 to 2 per week due to a lack of storage space for completed segments. Also, the delivery of solid rocket motor avionics components required for the second through fourth Titan IVs will be late, and solid rocket motor segments for the fifth Titan IV launch will be delivered 1 month late.

Delays at General Motors Delco Systems Operations are due to production start-up problems and parts shortages because of late deliveries from its vendors. Also, the 6th inertial guidance unit scheduled for delivery experienced a test failure, and the delivery dates have slipped for the 8th through 10th units.

General Dynamics was 4 months behind schedule on delivery of the first Centaur due to welding problems, inadequate planning, parts shortages, and concerns about tooling. It is revising the Centaur delivery dates.

Martin Marietta originally built a 100-day margin into the schedule to ensure that it would meet initial launch capability dates; however, this margin has now been used up, and any more schedule problems will delay production schedules. Program officials said the schedule variance will be reduced or eliminated by improving production efficiencies and/or by delaying production milestones.

Launch Schedules Have Been Delayed

The Air Force delayed 6 of the 10 launches planned for fiscal years 1989 and 1990. Also, the initial launch capability dates for three vehicle configurations and the launch capability dates for three launch facilities have slipped. Furthermore, the Air Force may not be able to launch four payloads planned for fiscal years 1990 and 1991 because launch vehicles will not be available.

Launches Have Slipped

Since 1988 the Air Force delayed 6 of the 10 launches planned for fiscal years 1989 and 1990. According to program officials, these launches were delayed because (1) the initial launch capability date for the Titan IV with the inertial upper stage was not met because of problems with space launch complex 41 and the launch vehicle, (2) complexes 40 and 41, after being modified for the Titan IV with the inertial upper stage, will have to be shut down and modified for the Titan IV with the Centaur upper stage and the Titan IV with no upper stage, (3) complex 4E modifications were behind schedule because the time needed to make the modifications was underestimated and a previous launch occurred later than planned, and (4) some planned payloads were delayed and rescheduled for a later launch.

Initial Launch Capability Dates Have Slipped

The Air Force's initial launch capability dates for three Titan IV configurations have slipped, as shown in table 4.1.

Table 4.1: Slippages in Initial Launch Capability Dates

Figures in months

Configuration and model number	Launch site	Initial launch capability date as of			Slippage		Total
		Apr. 1987	Mar. 1988	Sept. 1989	1987-88	1988-89	
Centaur upper stage (401)	Cape Canaveral	Feb. 1990	May 1990	Apr./June 1991	3	11-13	14-16
Inertial upper stage (402)	Cape Canaveral	Oct. 1988	Oct. 1988	Feb. 1989	0	4	4
No upper stage (403/404)	Vandenberg	Apr. 1989	Feb. 1990	Apr./June 1990	10	2-4	12-14

Model 401 initially slipped 3 months because the start of Centaur upper stage development was delayed due to inadequate funding for fiscal years 1985 and 1986, according to a program official. Since March 1988 the date slipped another 11 to 13 months because some Titan IV

launches were added at space launch complex 41, which delayed the facility becoming available for modification.

Model 402 slipped 4 months since March 1988 because additional time was required for testing the spacecraft on the launch pad and for validating the aerospace ground equipment. The Air Force declared initial launch capability in February 1989 because all vehicle hardware and systems were at the facility, which was ready to support launches, and all engineering testing was complete. The Air Force did not launch the first Titan IV with the inertial upper stage until June 14, 1989, because of schedule conflicts with other launches, as well as weather and flight and ground hardware problems.

Model 403/404 was initially delayed 10 months because its launch is scheduled after another launch from space launch complex 4E that was delayed. Since March 1988 it slipped another 2 to 4 months because the payload program office required that 3 different payloads be integrated to the vehicle. According to a program official, the payload program office will inform the Titan IV program office at a later date which of the 3 payloads it wants launched first.

Launch Facility Capability Dates Have Slipped

The launch capability dates for three of the four facilities have slipped, as shown in table 4.2.

Table 4.2: Slippages in Launch Facility
Capability Dates

Space launch complex	Capability dates		Slippage (months)
	Feb. 1988	Sept. 1989	
40	Sept. 1990 or Oct. 1991 ^a	Jan. to Mar. 1992	3-18
41	Oct. 1988 ^b	Apr. to June 1991 ^c	18-20 ^c
Second facility at Vandenberg	Oct. 1994 ^d	Apr. to June 1996	18-20

^aProgram officials provided two different dates.

^bAs of January 1988.

^cThe Air Force declared that it was capable of launching the Titan IV with the inertial upper stage from space launch complex 41 as of February 1989. Therefore, the slippage for that model was 4 months. The 18-20 month slip is for the Titan IV with the Centaur upper stage. The launch capability date for the Titan IV with no upper stage is classified.

^dAs of July 1988.

Space launch complex 40 was delayed because contract negotiations are taking longer than expected. Complex 41 was delayed for the Titan IV with the Centaur upper stage because some Titan IV launches were added, thus delaying its modification for the Centaur. Also, the modifications for the Centaur have increased significantly in scope. The second Vandenberg facility was delayed because of deliberations on whether to modify the mothballed space shuttle complex or build a facility. Also, DOD and Air Force officials said that 12 months of the delay was due to the Congress not providing any fiscal year 1989 funding. Furthermore, the Air Force did not provide the funding amounts requested for the program for fiscal years 1990 and 1991.

Additional Launch Delays May Occur

The Air Force will be short four vehicles—two each in fiscal years 1990 and 1991—because more payloads have been added to the Titan IV program. Program officials said the Air Force is considering three options to resolve the shortage: use vehicles from the follow-on buy, increase production capacity by adding more tooling and work shifts, and/or delay more launches.

A program official said the Air Force is considering adding more tooling and/or workshifts at Martin Marietta and/or some of its subcontractors. The Air Force already decided to increase payload fairing production by adding tooling at McDonnell Douglas. However, efforts to increase production would have no appreciable near-term effect because it takes 3-1/2 years to produce and deliver a Titan IV. Therefore, program officials said they will probably delay the launches if the payloads are available on time.

Performance Capabilities of Various Titan IV Configurations

Figures in pounds

Configuration	Performance requirement	Estimated capability	
		Feb. 1988	Aug. 1989
Centaur upper stage	10,000 to geosynchronous orbit	10,301	10,313
Centaur upper stage	11,500 to 12-hour orbit		11,500
Inertial upper stage	38,784 to 80 by 95 nautical mile, 28.6 degree orbit	38,961 ^a	39,169
Inertial upper stage	5,250 +/- 90 to geosynchronous orbit	5,261	5,250
Inertial upper stage	5,050 to 5,250 to geosynchronous orbit	5,208	5,175 ^b
No upper stage	32,000 to 100 nautical mile, 90 degree circular orbit	32,908	32,912
No upper stage	^c		
No upper stage	38,784 to 80 by 95 nautical mile, 28.6 degree orbit		39,169

^aAs of December 1987.

^bAs of September 1989. An inertial upper stage program official said that none of the payloads for this requirement are expected to weigh more than 5,175 pounds.

^cThe requirements and estimated capability for this configuration are classified. However, program officials said they will be able to meet the configuration's requirements by meeting the preceding configuration's requirements.

Performance Capabilities of Various Titan IV Configurations With the Solid Rocket Motor Upgrade

Figures in pounds

Configuration	Performance requirement	Estimated capability
Centaur upper stage	12,700 to geosynchronous orbit	11,500 ^a
Centaur upper stage	14,500 to 12-hour orbit	11,500 ^a
Inertial upper stage	^b	^c
No upper stage	38,800 to 100 nautical mile, 90 degree circular orbit ^c	^c
No upper stage	^e	38,134
No upper stage	48,800 to 80 by 90 nautical mile, 28.6 degree orbit ^c	^c

^aThe estimated capability of the Centaur upper stage is limited to 11,500 pounds because of structural limitations.

^bProgram officials said no requirement and capability estimates have been developed for this configuration, but they may be developed by the mid-1990s.

^cThese requirements are from the Air Force Program Management Directive. All other requirements are system specifications from the users.

^dProgram officials have not yet estimated the performance capabilities of these configurations.

^eThe requirements are classified.

Selected Acquisition Report Cost Estimates for the Titan IV Program

The Selected Acquisition Reports from 1985 to 1988 showed that the Titan IV program cost estimate increased by \$9.7 billion. Most of that increase—\$7.1 billion—occurred between the 1987 and 1988 estimates, mainly because 34 vehicles, the solid rocket motor upgrade, Vandenberg and Cape Canaveral launch facilities, payload integration, and subcontractor incentives were added to the 1988 estimate. Table III.1 details these and other changes.

Table III.1: Selected Acquisition Report Cost Estimates

Dollars in millions

	1985	1986	1987	1988	Percent change since 1987
Research, development, test, and evaluation	\$641.1	\$799.3	\$1,359.2	\$1,987.0	46.2
Procurement	1,888.1	3,315.3	3,559.3	9,994.8	180.8
Military construction	0.0	220.0	215.0	219.5	2.1
Total^a	\$2,529.2	\$4,334.6	\$5,133.5	\$12,201.3	137.7
Total cost per vehicle	\$252.9	\$188.5	\$223.2	\$214.1	-4.1
Total cost per launch	50.1 ^b	38.2 ^b	37.9	39.7 ^b	4.7
Total cost per vehicle plus launch	\$303.0	\$226.7	\$261.1	\$253.8	-2.8
Number of vehicles procured	10	23	23	57	147.8

Note: The cost estimates in the 1985 through 1987 reports are through fiscal year 1993; the estimates in the 1988 report are through 1995.

^aAccording to a program official, the 1985 through 1987 reports did not include other user funding for developing the Titan IV without an upper stage or for modifying space launch complex 4E, which was an oversight by the program office. The official said the 1988 report estimates included these costs.

^bThese estimates are in fiscal year 1985 dollars.

Although the total program cost estimates in the reports are accurate, the specific amounts reported for the research, development, test, and evaluation and procurement appropriations are not, according to program officials, because the reports include funding by other users in the procurement appropriation. A program official said the Air Force uses this reporting practice to help ensure that the appropriations and amounts from other users remain classified. Therefore, the procurement estimates are overstated, and the research, development, test, and evaluation estimates are understated.

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